JACOBS
ESSSA Group

Improving Photometric Calibration of Meteor Video Camera Systems

Steven Ehlert (Qualis), Aaron Kingery (ERC), & Bill Cooke (NASA)
Meteoroid Environment Office
Meteoroids 2016

Overview

- The need for better calibration
- Understanding Camera Linearity
- Synthetic Magnitudes
- Performance
- Future Prospects
- Watec 902 Ultimate Cameras with gamma=LO

JACOBS
ESSSA Group

Why Revisit Calibration?

- Prompted by new color camera system
- Everything improves as calibration gets better

JACOBS
ESSSA Group

The Calibration Problem

- Typical calibration model is dereived from reference stars, frequently parameterized as

$$M_{cat} - M_{raw} = zp + \kappa \times \chi + CC \times (B - V)$$

Extrapolating this to meteor photometry is not always trivial

JACOBS
ESSSA Group

The Calibration Problem

Property	Reference Stars	Meteors
Cameras	Linear CCD	Nonlinear video
Filters	UBVRI or ugriz	Unfiltered
Spectra	Thermal	Line dominated
Brightness range	Sweet spot	Very bright to very faint

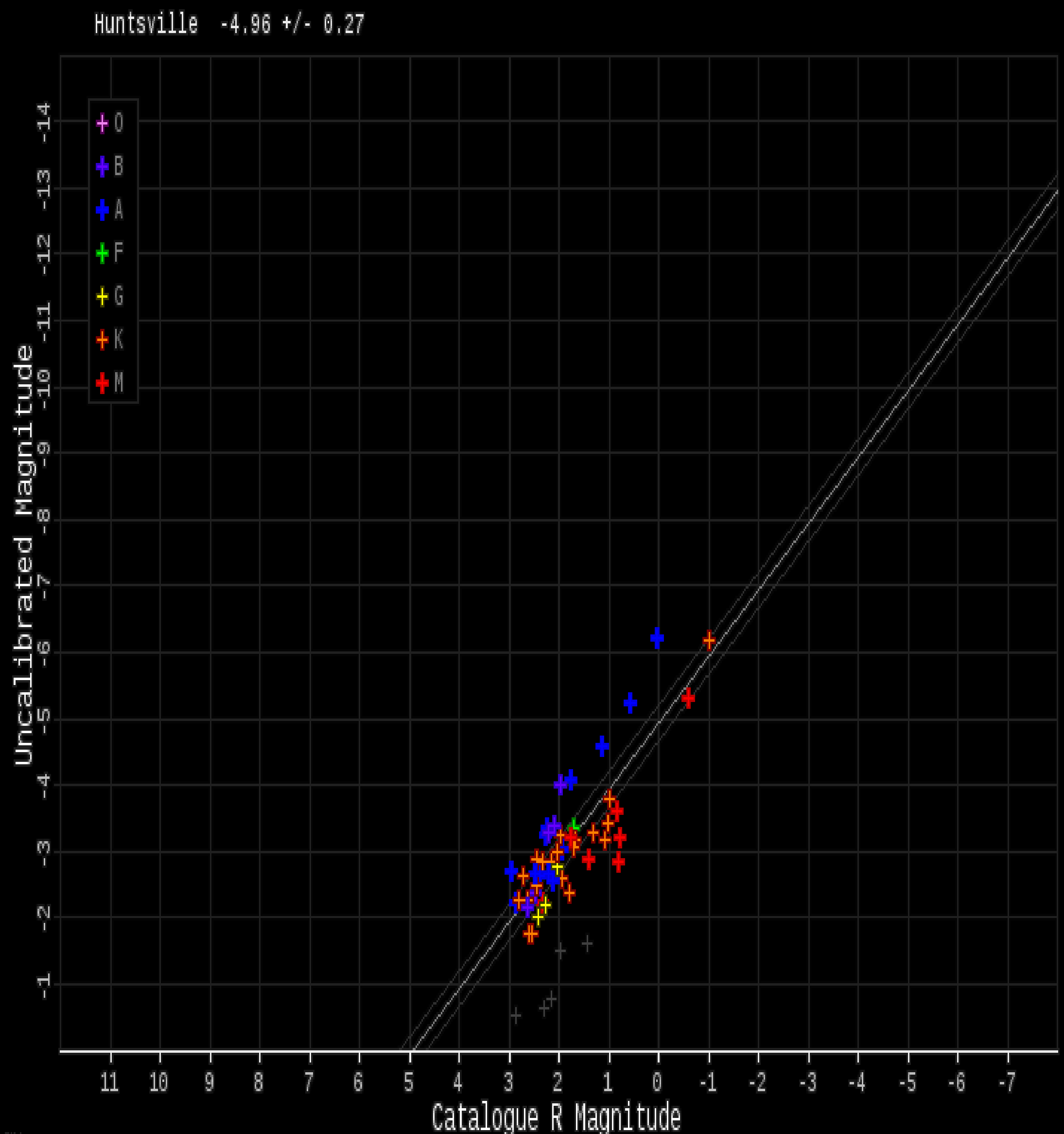
Without proper linearity and color corrections, we do not know how wrong we are

JACOBS
ESSSA Group

How bad is it?

Segregation between red and blue stars: 0.5 mags

What is the color of a meteor?



JACOBS ESSSA Group

Just what does it mean when we say gamma=0.45?

TESTING THE GAMMA CORRECTION

JACOBS
ESSSA Group

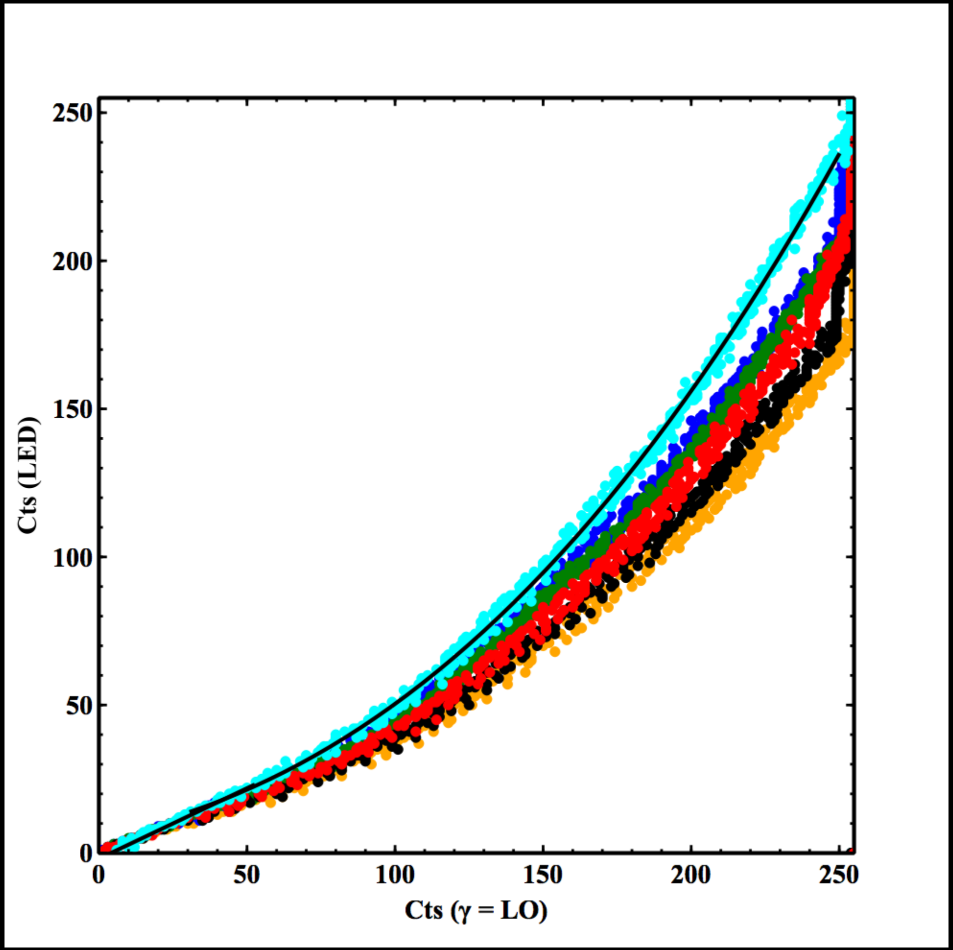
Testing the Linearity

- We performed two sets of tests to check the response of the camera
  - NASA's video calibration lab
  - LED with brightness controlled by an Arduino computer board
  - Total cost of LED setup is ~$100 and a few hours to run tests
- All tests done at 'field' settings

JACOBS
ESSSA Group

LED Test Results

- Linear and power-law components
- Power-law is consistent with gamma=0.45
- Eight cameras tested – results did vary



JACOBS
ESSSA Group

Setting our own standards

SYNTHETIC MAGNITUDES

JACOBS
ESSSA Group

Synthetic Magnitudes

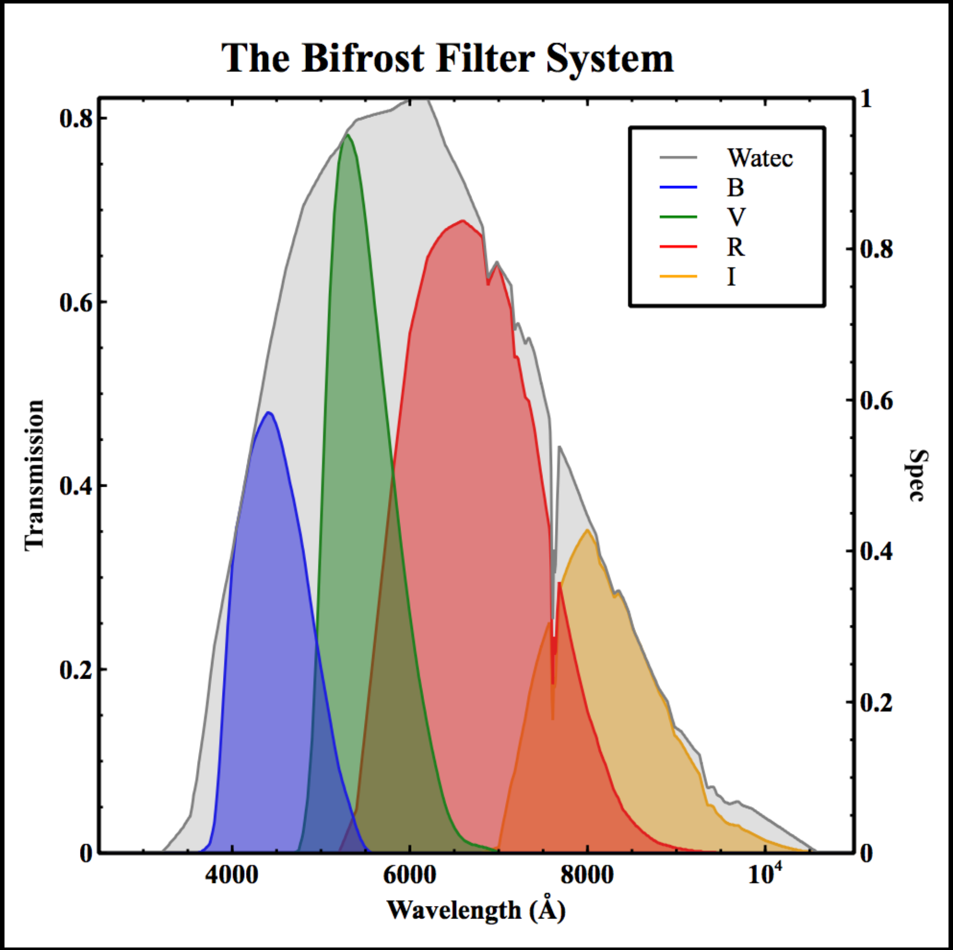
- Do not transform the meteor flux into a standard system
- Instead, bring the reference stars into your detection system
- Calculations are easy to do with PySynPhot from STSci
- Need to use 3-part spectral types (e.g. G2V) whenever possible

JACOBS
ESSSA Group

Bandpasses

Sky 2000 catalog + bandpass models allow us to create 5-filter reference catalog normalized to Vega

Caveat: We do not have the equipment to measure the bandpasses ourselves



JACOBS ESSSA Group

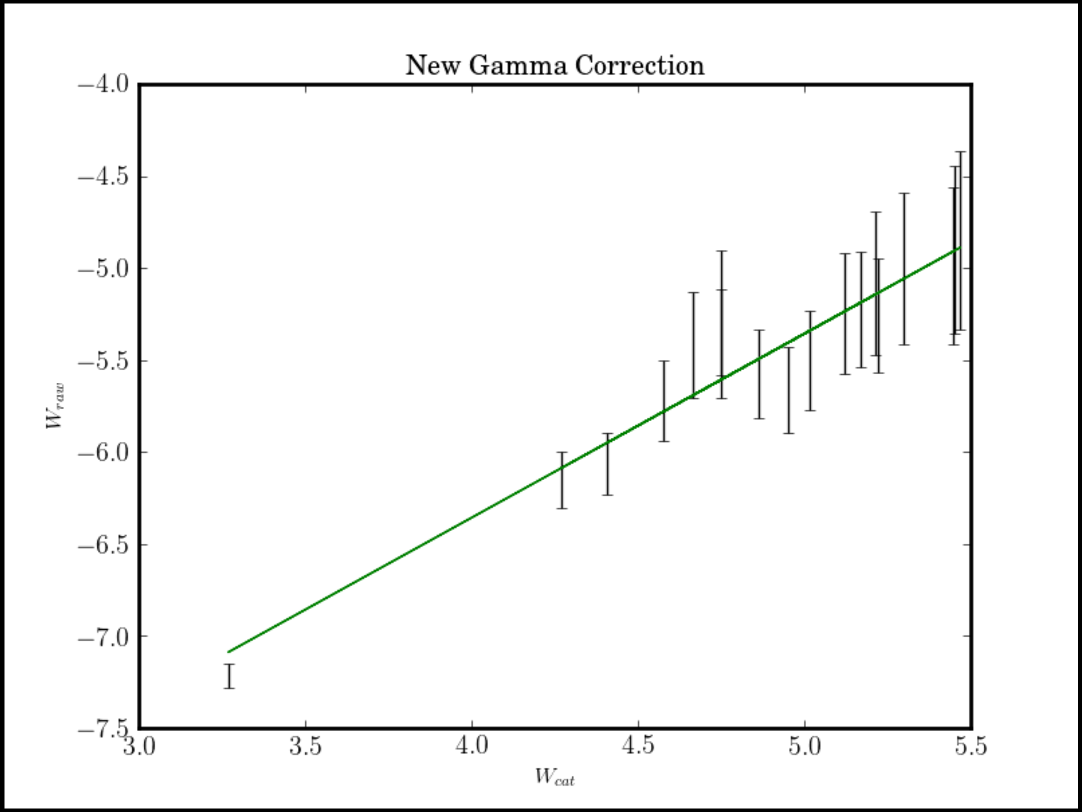
Utilizing our new synthetic magnitude catalog and gamma correction

PERFORMANCE WITH VIDEO DATA

JACOBS
ESSSA Group

Unfiltered

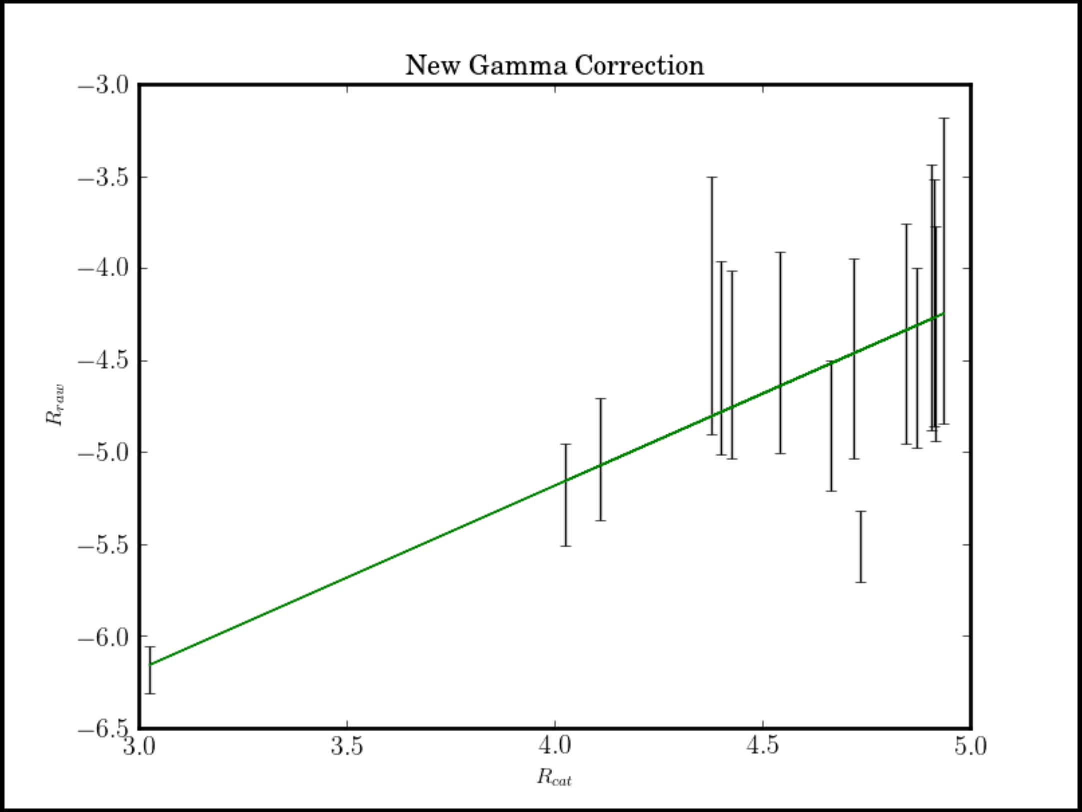
- ZP uncertainty is ~ 0.06 mag
- Systematics: 0.18 per star
- Accounts for systematic/modeling uncertainties in bandpass shape and stellar spectra, determined using wide field CCD observations



JACOBS
ESSSA Group

R-band

- ZP uncertainty is ~ 0.10 mag



JACOBS
ESSSA Group

Limiting Factors

- Better reference star data: assuming single spectrum for each spectral type is a modeling deficiency
- Better synthetic magnitudes: measure bandpasses in lab
- Saturation correction has not been determined

Conclusions

- Lab tests have helped to greatly improve our photometric calibration
- Specifically addresses linearity and color term systematics
- Test cameras at field settings before deployment- the results might surprise you

JACOBS
ESSSA Group

Acknowledgements

- Walt Lindblom in Video Calibration Lab
- Space Telescope Science Institute for SynPhot
- The rest of the MEO for supporting this effort

JACOBS
ESSSA Group